Greening Development to Protect Watersheds

Does New Urbanism Make a Difference?

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New urbanism has been touted as a more environmentally sustainable form of development than conventional low-density sprawl. To test this assertion, this study comparatively evaluates how well 50 matched pairs of new urban and conventional developments in the United States integrate watershed protection techniques. Findings indicate that new urban development practices offer a greener and more compact alternative to sprawl in greenfields on the suburban fringe, as they are more likely to protect and restore sensitive areas, reduce impervious cover, and incorporate best management practices. New urban developments in infill sites are more likely to incorporate impervious surface reduction techniques and restore degraded stream environments, but have equivalent levels of sensitive area protection and use of best management practices. Recommendations offer ways in which watershed protection techniques can be used to implement more environmentally sustainable development.

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New urbanism has been widely acclaimed as a more environmentally sustainable form of development than conventional low-density development that results in sprawl. Sprawl increasingly dominates the landscape by converting vast expanses of land into roads, parking lots, roofs, and driveways. These impervious surfaces generate polluted runoff that is recognized as a leading threat to water quality (Environmental Protection Agency, 1994), as well as increase downstream flooding and habitat loss (White et al., 1999). In contrast, new urban development patterns require considerably less land and impervious surfaces, and have been touted as more supportive of conservation goals, including water quality protection and flood mitigation (Congress of the New Urbanism, 2001).

The new urban design concept has drawn increasing attention from land use and environmental policymakers. Communities in major drainage basins such as the Lake Tahoe area of California, Chesapeake Bay in Maryland, and Neuse River in North Carolina must adopt plans that promote development patterns that reflect the high density and mixed-use elements of new urbanism as part of comprehensive management strategies to achieve mandated reductions in nutrient inputs (see, e.g., Maryland Department of the Environment, 1995; North Carolina Department of Environmental and Natural Resources, 2002). Since the mid 1990s, 10 states have adopted "smart growth" legislation that requires or encourages local governments to alter development practices dominated by low-density sprawl and create more compact urban forms that reflect new urbanism (American Planning Association, 1999; Godschalk, 2000). An increasing number of local governments are experimenting on their own with specific plans, policies, codes, and development standards that promote new urbanism (Eppli & Tu, 1999).

Many observers of these state and local initiatives agree that in addition to social and fiscal benefits, new urbanism offers a more environmentally compatible form of development than sprawl (Burchell et al., 2002; Godschalk, 2000; Pollard, 2001).

Despite the growing attention given to new urbanism, there has been little empirical study of how well this design promotes environmental protection (Berke, 2002), especially effective stormwater management and watershed protection. Prior to the 1960s, the principal concern with urban stormwater runoff was safety and property protection. Emphasis had been on directing and draining water off paved surfaces as quickly as possible with little regard for increased downstream flooding and pollution. Regulations have been expanded in recent decades to require developers to use best management practices (BMPs) to detain and filter polluted runoff. However, BMPs treat runoff only as a symptom of development and do not address land use and site design characteristics of development (e.g., shape, location, density, amount, and types of uses) that are the ultimate causes of runoff. Water resource specialists have therefore increasingly emphasized the importance of land use and site design as part of a comprehensive approach to watershed management (Arnold & Gibbons, 1996; Center for Watershed Protection, 1998).

This article fills a void in the literature on new urbanism by describing an empirical study of how well this urban design supports more environmentally sustainable development. The conceptual framework relates new urban design to the goals of watershed protection that this design is intended to support. We then use the framework to comparatively evaluate 50 matched pairs of new urban and conventional developments in five U.S. states in the South Atlantic Coast region (Georgia, Maryland, North Carolina, South Carolina, and Virginia). We differentiate developments by type of location to determine whether new urban developments built on greenfield or infill sites are more likely to account for watershed protection than conventional low-density developments.

The Promise (and Pitfalls?) of New Urbanism

New urbanism (or neo-traditional development) has its roots in the dense, pedestrian-scale towns of the 19th century. This high-density development pattern mixes different land uses, including homes, shops, schools, offices, and public open spaces (Calthorpe, 1993; Duany & Plater-Zyberk, 1991). Streets are narrow and pedestrian friendly to encourage bicycling and walking in place of driving automobiles. Homes feature front porches and short setbacks from streets (not prominent garages and long driveways) to create streetscapes that are designed for people, not automobiles.

A major goal of new urbanism is to reduce driving distances (and street lengths) between locations, and thus increase the viability of nonauto modes of travel and reduce the demand for parking spaces. However, new urban developments have generally not achieved the desired levels of nonauto modes of travel that were originally publicized by new urbanists (Crane, 1996). Factors related to the lack of success are often beyond the control of new urban site designers, such as the absence of clustered employment destinations that support transit use, inadequate provision of transit service, and socioeconomic and lifestyle characteristics of residents that dictate rates of private auto use (e.g., the growing demand for SUVs by upper-income households).

New urban development designs are also intended to maximize open space without reducing the number of dwelling units that can be built. The aim is to concentrate development in return for more open space. The high density provides more opportunity to protect hydrologically sensitive areas (e.g., steep slopes, porous soils, forested sites, wetlands, and stream buffers) and reduce the size of individual lots and the lengths of streets compared to conventional development codes that contain rigid standards for minimum lot size and street dimensions. However, due to the limited attention given to conservation in new urban design codes (Calthorpe, 1993; Duany Plater-Zyberk & Company, 2001), new urban developments may not be taking full advantage of opportunities to protect sensitive areas.[1]

Conventional low-density development evolved over the past 50 years to accommodate population growth and led to the American public's growing dependence on autos. Key features of this pattern of development include large-lot subdivisions that are widely separated from strip commercial centers and work places. Streets are wide to permit unimpeded vehicular movement. Residential lots have deep frontage setbacks, with large lawns and driveways.

In the case of watershed protection, conventional low-density developments generally create more impervious surface that generates more runoff than do new urban developments. Although large lots may have less impervious surface per lot, the longer roads and driveways, as well as larger parking lots, make the overall design more impervious. Schueler (1994) estimated that compact development can reduce site imperviousness by 10 to 50%, depending on lot size and road network.[2]

While there is little research that evaluates the effectiveness of new urban development regarding watershed protection, the available evidence indicates some advantages of this type of development. A study in the Charleston (SC) Harbor Area compared runoff impacts of a conventional low-density development scenario to a new urban development scenario in the same watershed (South Carolina Coastal Conservation League, 1995). Findings indicated that for the same amount of development, conventional development consumed eight times more land (see Figure 1) and generated 43% more runoff, three times as much sediment, and higher loadings of nitrogen and phosphorous than the new urban design. However, this study examined only the effects of impervious surface and not impacts related to the position of the development in the watershed, which affects watershed hydrologic functions and resultant changes in runoff and pollutant loading.

A study in Olympia, Washington, evaluated impervious surface coverage produced under conventional development regulations and under proposed changes to the regulations (City of Olympia, 1994, 1996). The study concluded that a 20% reduction in future impervious cover is a feasible and practical goal for Olympia. While this study focused on the effects of conservation design of residential subdivisions (Arendt, 1996), many of the recommended changes promote key features of new urbanism (e.g., reduce street width standards, use cluster rather than large-lot land uses to reduce street length, and reduce excessive parking lot requirements for commercial uses). If Olympia were to incorporate the recommendations in projected development over a 20-year period, about 600 acres of impervious coverage would be eliminated.

As noted, a shortcoming in the literature on new urbanism is the lack of attention to conservation concerns, especially watershed protection.[3] New urban development codes support the basic goals of community character, sense of place, and pedestrian movement (Calthorpe, 1993; Duany Plater-Zyberk & Company, 2001). These codes include detailed standards for building disposition, configuration and function, as well as parking, civic space, and streetscapes. However, previously published design standards for watershed-based zoning, green parking lots, headwater street geometry, and the dimensions of stream buffers have not been acknowledged and used (see, e.g., Center for Watershed Protection, 1995; Schueler, 1995).[4] New urbanists are typically more concerned with community architectural character, sense of place, and pedestrian-oriented design.

While these important gaps potentially erode the basic ecological premises of new urbanism, the concept has experienced a parallel rise in success in capturing the attention of a wide audience. New urbanists have been influential in instigating public awareness and understanding of alternative ways of community building and improving prospects for environmental sustainability. Their boldness in initiating a powerful critique of the dominant pattern of development (suburban sprawl) has gained public support and by 1999 had inspired over 200 development projects throughout the country (Eppli & Tu, 1999). The major question is whether the promise of new urbanism has translated into more environmentally sustainable development.

Source: South Carolina Coastal Conservation League (1995)

FIGURE 1. Design scenarios for the 583-acre Belle Hall site in Mount Pleasant, SC. Each provides equivalent development, but the new urban scenario (right) contains much more open space.

Conceptual Framework

Low-Impact Design Techniques and New Urbanism

We focused on low-impact development design techniques for watershed protection to gauge how well new urban and conventional development projects achieve environmental protection. These techniques include a broad range of approaches. We draw on a prior conceptualization of low-impact design that specifies three categories of techniques (Center for Watershed Protection, 1995, 1998; Jones, 2001):

- protection of hydrologically sensitive areas (e.g., porous soils, steep slopes, forested lands);
- reduction of impervious surfaces of the built environment; and
- best management practices to detain and filter stormwater (e.g., bioretention ponds, grass swales, infiltration basins, and landscaping).

Although research that evaluates the impacts of new urban design on the environment is in the early stages, there is an emerging consensus about specific design features that are key to examining these impacts. Prior research suggests that three design features can be used as a common conceptual basis to compare the impacts of new urban and conventional developments: low versus high density; auto versus pedestrian orientation; and mixed versus single use. These features have been used to analyze the impacts of both designs on transportation systems (Crane, 1996) and on social and psychological well-being (Brown & Cropper, 2001). Table 1 illustrates the hypothesized influence of these design features on use of low-impact design techniques for watershed protection if a development incorporates the high density, mixed uses, and pedestrian orientation of new urban design.

Density

New urbanists are clear that net density of new urban development should be higher than that of conventional suburban developments. Net density is the number of dwelling units per acre in residential use, while gross density includes the land area plus associated streets, alleys, and undeveloped open spaces (Kaiser et al., 1995). Calthorpe (1993) indicates that seven dwelling units per acre is a minimum threshold of net density for new urban developments, compared to four dwelling units per acre (or less) for conventional developments.

In theory, higher densities than those of conventional developments are expected to achieve several positive environmental outcomes associated with watershed protection (Center for Watershed Protection, 1995, 1998). By permitting high density, smaller lots accommodate an equivalent number of housing units as in a conventional development in return for open space within the new urban development site and/or in the surrounding area. This development pattern offers more opportunities to increase the distance from impervious areas to a stream and protect functional open spaces (rather than create fragmented spaces on individual lots) required for aquatic buffers and hydrologically sensitive upland areas.

High density makes targeted restoration projects for sensitive areas (streams, riparian zones, wetlands) more feasible since compact new urban developments confine adverse environmental impacts to specific subbasins rather than spreading impacts across the landscape.[5] High density also reduces impervious cover in various ways. Shallow front yard setbacks designed to facilitate conversations between residents and pedestrians also reduce the length of driveways. Theoretically, shorter street length between lots may foster nonauto travel and thus reduce demand for parking spaces. Impervious cover is further reduced as zero side-yard setbacks provide opportunities for shared roofs among housing units rather than a separate roof per unit. Higher density also leads to smaller building footprints through multilevel structures. Finally, high densities provide more room to locate effective stormwater BMPs that use stormwater detention and infiltration systems in the open space.

Pedestrian Orientation

Pedestrian orientation includes factors that reduce the salience of automobile use but also provide beneficial effects for watershed protection. Narrow streets in grids spread out and calm traffic and require less impervious surface area than conventional designs that use wide, straight streets to facilitate traffic flow. On-street parking slows the flow of traffic and "civilizes" the street for pedestrians by creating a buffer between moving cars and the sidewalk, and it places parking near the desired street-side building entries (Calthorpe, 1993). This additional space for parking helps replace large impervious surfaces of off-street parking structures and private driveways. Various landscaping features integrated into street design (e.g., street trees and below-grade, landscaped medians between sidewalks and streets) create streets that are intended to encourage pedestrian use and can enhance stormwater infiltration.

Greenways provide pedestrian and bikeway connections among residential, commercial, and civic areas, while also protecting sensitive open spaces. However, given the emphasis on nonauto modes of travel in new

TABLE 1. Low-impact design techniques and hypothesized outcome by new urban design feature.

	New urban design feature		
Low-impact technique	High net density	Pedestrian orientation	Mixed use
Protection of sensitive areas	+ Less individual lot space, more common open space + More potential to restore due to confined impacts	+ Narrow streets means more opportunities for open space protection – More demand for paved greenways for pedestrian and bike movement	+ Seamless integration rather than segregation among land uses creates opportunities for common open space
Reduction of impervious surfaces	+ Short street length + Short driveways + Shared alleyways + Less roof surface	+ Narrow street width + On-street parking instead of large driveways and parking lots + Reduced building footprint through multi-level structures – More demand for paved sidewalks on both sides of streets – More demand for paved greenways for pedestrian and bike movement	+ Shared parking to reduce size of parking lots + Encourage pedestrian accessibility to reduce demand for parking
BMPs to detain and filter stormwater	+ More room to locate effective BMPs	+ Curbside landscaping for detention and infiltration	+ Seamless integration rather than segregation of land uses creates common open spaces for BMPs

Note: Effect of use of technique: – means negative effect; + means positive effect.

urban developments, greenways are more likely than conventional development to include impervious paths and trails to accommodate walking and biking.

Mixed Uses

New urbanists criticize the segregation of land uses that separate homes from jobs and shops, rich from poor, and owner from renter (Calthorpe & Fulton, 2001; Duany, et al., 2000). The criticism is based on various grounds, including a loss of social interaction among people of different incomes and household structures and declines in sense of place and air quality due to the dominance of the automobile. According to the *Charter of the New Urbanism*, a widely accepted statement of the principles of new urbanism, "a broad range of housing types and price levels can bring people of diverse ages, races, and incomes into daily interaction, strengthening personal and civic bonds essential to an authentic community" (Congress of the New Urbanism, 2001, n.p.). The *Charter* also advocates the mixing of residential and commercial uses in relatively fine grain patterns of land use that are integrated at the scale of the block, lot, or even individual building (e.g., commercial uses on the ground floor and residential above).

While new urban projects sometimes experience difficulty in attracting retail and office land uses, this design feature can potentially reduce the amount of land to be covered by impervious surfaces for parking. Placement of business and civic uses next to residential uses increases pedestrian accessibility and relieves pressures for parking spaces (Ewing, 1996). Demand for parking spaces can be further reduced by comparing peak demands of different land uses by time of day, day of the week, and season and locating land uses with different peak demand times near each other (City of Olympia, 1996). Peak parking demand for different land uses is often generated at different times during the day, week, or season (e.g., evening for movie theaters and daytime for offices). Varied parking demand for proximate uses allows joint use of the same parking spaces, thus reducing the total number of spaces needed to accommodate all uses (Bartman-Aschman Associates, 1983; City of Olympia, 1996). Another advantage of mixing complementary uses is the ability to generate multipurpose trips that would otherwise be separate trips to segregated uses. A single parking space can serve several trip purposes, which further decreases demand for spaces and thus reduces impervious cover. Finally, the reduced demand for parking created by mixed uses also creates more room for open spaces and BMPs (Ewing, 1996).

Research Design, Data Collection, and Analysis

This study is part of a larger one focused on determining how new urban developments influence use of low-impact design techniques for watershed protection, and on the impacts such developments have on watersheds. This article represents the first stage of the broader study, examining the development patterns behind use of low-impact design techniques.

Our data on integration of low-impact design techniques into new urban and conventional developments come from a survey of local governments in five states: Georgia, Maryland, North Carolina, South Carolina, and Virginia. These states reflect the range of environmental regulatory provisions governing land use and watershed protection that are found among all states. Maryland is widely recognized as a leading state based on enactment of statewide smart growth legislation in 1997 (Godschalk, 2000). This state also has a stringent nutrient reduction strategy requiring local jurisdictions to protect sensitive areas in the Chesapeake Bay drainage basin under the Chesapeake Bay Agreement of 1987 (Maryland Department of the Environment, 1995). North Carolina and Virginia are moderate in strength but for different reasons. North Carolina's coastal planning mandate of 1974 is moderately strong, requiring sensitive area regulations and local plans (Berke & French, 1994). However, the mandate covers only coastal jurisdictions, and the state's environmental mandates are weak. Virginia adopted a moderately strong nutrient reduction strategy to be followed by communities in the Chesapeake Bay drainage basin under the Chesapeake Bay Agreement (Virginia Department of Environmental Quality, 1996), but has somewhat weak environmental requirements for the remainder of the state.[6] Georgia's and South Carolina's environmental protection requirements are generally weak.

An exploratory approach was used in developing the study population of both types of developments. The initial task was to identify new urban developments based on the following procedure. Through three new urban-oriented Web sites, the *New Urban News* newsletter, and published case studies of new urban projects, an initial list of new urban developments was identified. The list was expanded, based on information gleaned from telephone interviews with planners from local governments that have in their jurisdictions new urban developments that were included on the initial list. Local planners were asked if they knew of other new urban developments in their region (and state) that were not included on the initial list. Projects that were smaller than 10 acres, or did not include a mix of land uses, or were not completed (or at least under construction) were excluded, since they were not considered to reflect new urban design features. Through this procedure, 54 new urban developments were identified in 34 local jurisdictions in the five states.

The next task involved development of a control group of conventional developments. Through telephone interviews, the key local government planning staff member who was most familiar with and involved in the permit review process for new urban developments in each local jurisdiction was identified. Next, each planner was asked to identify a conventional development in their community that was most comparable to the new urban development in terms of acreage, percent completed, number of housing units, and location type (greenfield or infill). Moreover, because construction of new urban developments began during the past decade (the first in our study was Kentlands of Gaithersburg, Maryland, in 1990), planners were asked to identify conventional developments that were completed in 1990 or later.

All 54 pairs of new urban and conventional developments were then sampled between February 2000 and August 2001. A round of telephone interviews was administered with the key local planning staff member for each pair of developments. For each pair, three sets of questions were designed to determine whether a given development incorporated techniques that protect sensitive open spaces, reduce impervious cover, and support BMPs that retain and infiltrate stormwater. Another question was designed to identify whether each development was located on a greenfield or an infill site. A *greenfield* is defined as an open space site adjacent to or outside an existing urban development boundary. An *infill* is an open space or previously developed site that was redeveloped as a new urban (or conventional) development and is located within an existing urban development boundary.

If a local government had more than one new urban development within its jurisdiction, the planner was asked to answer the questions for each matched pair of developments. For some questions, staff from other local agencies (e.g., public works and environmental services) were interviewed if the planner indicated that these staff were more knowledgeable and better able to respond accurately. Questionnaires were completed for 50 of the 54 pairs of development projects (92.6% response rate).[7] Table 2 lists the names and locations of the new urban developments included in the sample.[8]

While our aim was to identify matched pairs of new urban and conventional developments, there were several dissimilarities in contextual characteristics (number of housing units, number of acres, and percent completed toward build-out) across the two groups.[9] Ordinary least squared regression was then used to test the effects of new urbanism on the extent to which low-impact design techniques are used in the greenfield and infill groups, while controlling for the contextual characteristics. The dependent variables were the sum of the number of techniques used for each of the three sets of watershed protection techniques that are listed in Tables 3, 4, and 5. The independent variables were the three contextual characteristics (number of housing units, number of acres, and percent completed toward build-

TABLE 2. New urban developments by state and location.

State	Infill site: Name—location	Greenfield site: Name—location
Georgia	Carver—Atlanta Lindbergh Station—Atlanta Smyrna Village—Smyrna Western Village—Atlanta	Monarch Village—Stockbridge Riverside—Atlanta
Maryland	Flaghouse Court—Baltimore Pleasant View Gardens—Baltimore The Terraces—Baltimore	Clarksburg Town Center—Clarksburg Fallsgrove—Rockville Kentlands—Gaithersburg King Farm—Rockville Lakelands—Gaithersburg
North Carolina	Boone Development—Davidson Earle Village—Charlotte	Afton Village—Concord Birkdale Village—Hunterville Caldwell Station—Cornelius Carpenter Village—Cary Cheshire—Black Mountain Cline—Conover Cornelius—Cornelius Deer Park—Davidson Falls River—Raliegh Kinderton—Davie County Laberi Project—Davidson Rosedale Commons—Huntersville Southern Village—Chapel Hill The Green at Scotts Mill—Apex Trillium—Cashiers Vermillion—Huntersville
South Carolina	Broad Street—Beaufort Port Royal—Port Royal	Battery Point—Beaufort Daniel Island—Charleston Harmony—Georgetown County I'ON—Mount Pleasant Village of Baxter—Fort Mill
Virginia	Avalon at Arlington Ridge—Arlington Cameron Station—Alexandria Carlyle—Alexandria Clarendon Center—Arlington County Pentagon Row—Arlington County Reston Town Center—Reston Westbury—Portsmouth	Belmont Bay—Prince William County Belmont Green—Loudon County Lorton Town Center—Fairfax South Bridge at Cherry Hill—Prince William County

out), plus the dummy variable for new urbanism. For each of the three dependent variables, regression analyses revealed that the contextual characteristics were not strong predictors of the extent of use of low-impact design techniques for the greenfield and infill groups.[10] These results thus allow us to be more confident about the effects of the type of development (new urban versus conventional) on the use of low-impact design techniques for watershed protection.

The main methodological limitation was the small number of matched pairs of developments for the greenfield and conventional development groups. Because of small cell sizes, statistical tests for mean and percentage values for each category of low-impact design techniques are not particularly useful. Significance test results are presented for those readers who desire such reporting, but the interpretation of findings is based on overall patterns more than on statistical results. These data limitations reveal the exploratory nature of the comparisons that follow.

Does New Urbanism Make a Difference?

Efforts to protect or restore hydrologically sensitive areas such as streams, floodplains, and natural drainage depressions have a major influence on the health of watersheds. Site design of a development is a critical element in maintaining stream morphology, watershed hydrology, water quality, and biodiversity (Center for Watershed Protection, 1995, 1998). Table 3 shows comparisons of the percentages of new urban and conventional developments in greenfields and infill sites in the study that protect sensitive areas (steep slopes, natural drainage depression, and buffers), restore them (floodplain and steam restoration and stream bank stabilization), and do not permit impervious uses in them.

In greenfields, the new urban developments were considerably more successful than the conventional developments in protecting and restoring sensitive areas and protecting open spaces. Specifically, they were at least twice as likely to protect steep slopes (56% versus 28%) and natural drainage depressions (53% versus 19%), while 88% protected buffers versus 66% of conventional developments. Moreover, the new urban developments were twice as likely or more to incorporate all three restoration activities (41% versus 16% for stream restoration, 56% versus 25% for floodplain restoration, and 38% versus 19% for stream bank stabilization). As noted in our conceptual framework, these findings are not unexpected, since new urban development designs offer more opportunity to protect and restore sensitive areas. Moreover, most conventional developments are limited in protecting any land except unbuildable wetlands, floodplains, and steep slopes.

In infill sites, however, these differences were not as salient. A slightly lower percentage of new urban developments protected steep slopes (11% versus 28%), and both groups were equally likely to protect buffers (28% each). Only natural drainage depressions were protected in a greater percentage of new urban than conventional developments (39% versus 28%). The new urban developments were only slightly more likely to incorporate the three restoration activities (28% versus 11% for stream restoration, 28% versus 17% for bank stabilization, and 17% versus 11% for floodplain restoration).

The greater emphasis on protecting and restoring sensitive areas in greenfields is likely due to more opportunities for establishing common open space networks than in infill areas that were previously built up. Streams

TABLE 3. Percentages of developments that protect and restore sensitive areas.

	Greenfield (%) [n = 32]		Infill (%) [n = 18]	
Sensitive areas	New Urban	Conventional	New Urban	Conventional
Steep slopes	56	28**	11	28
Natural drainage depression	53	19***	39	28
River, stream, floodway buffer	88	66**	28	28
Stream restoration	41	16**	28	11
Stream bank stabilization	56	25**	28	17
Floodplain restoration	38	19*	17	11[a]
Impervious uses not permitted in sensitive areas	25	37	39	83***

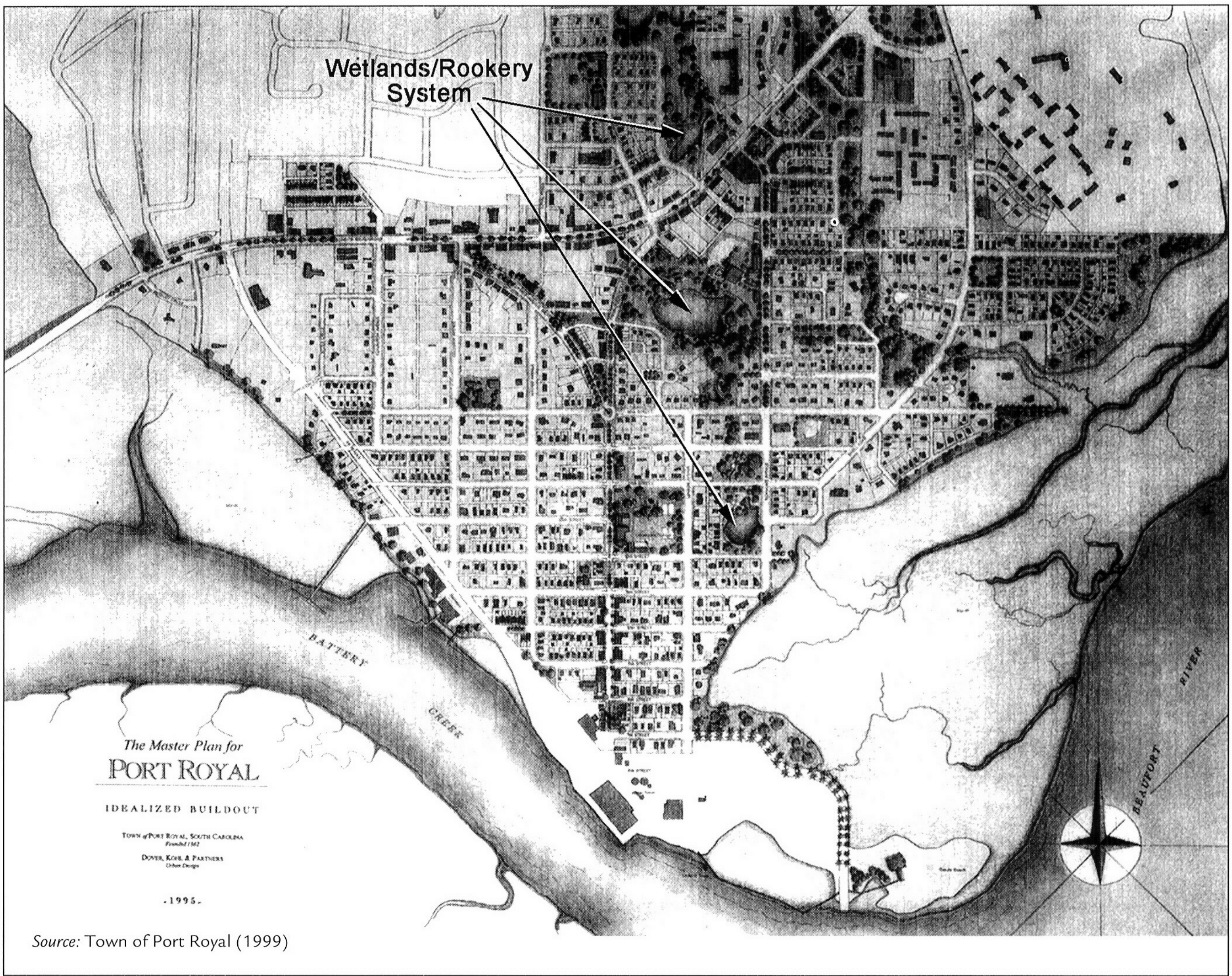
Note: Comparisons show Chi square values that are significantly different for $*p < .1$ $**p < .05$ $***p < .01$.

a. Not applicable: Chi square tests not valid, as 50% or more of cells had frequencies less than 5.

in infill areas are likely to be so seriously degraded and/or piped underground that developers and local jurisdictions do not consider improvement efforts to be worthwhile. Further, although practitioners of new urban design are increasingly giving higher priority to crafting development codes and building projects that embrace environmental protection, the emphasis is on greenfields, not urban infill sites (e.g., Duany Plater-Zyberk & Company, 2001).

Despite limited support for watershed protection in infill sites, our data reveal innovative initiatives in integrating low-impact design techniques into infill developments. For example, Figure 2 shows the new urban redevelopment design of Port Royal in South Carolina that incorporated an integrated wetland protection and restoration strategy. Key elements of this design include restoration of wetlands from a fragmented to an interconnected system that simultaneously supports pollution reduction, flood storage, and wildlife habitats (see Figure 3). This design also involved the reconfiguration of a depressed commercial strip development to a mixed-use design to facilitate revitalization of this area of town.

Avoidance of impervious uses in open spaces was the only instance where new urban developments did not protect sensitive areas as extensively as conventional developments. In greenfields, 25% of the new urban developments do not permit impervious uses compared to 37% of the conventional developments. This distinction was even more pronounced in infill areas, with 39% of the new urban developments not permitting impervious uses compared to 83% of the conventional developments. The lower percentage is not unexpected, since



Source: Town of Port Royal (1999)

FIGURE 2. Port Royal, SC, new urban redevelopment master plan with wetlands/rookery system.

FIGURE 3. Port Royal, SC, new urban redevelopment site. Restored natural wetland and water retention facility also serves as a waterfowl rookery.

new urban developments are designed to foster nonauto modes of transportation. This translates into more paving of open spaces for bikeways and walkways, especially in infill sites where demand for nonauto modes of travel would be higher than in greenfields.

The second type of low-impact design techniques is concerned with impervious cover associated with roads, driveways, parking areas, buildings, and sidewalks. Impervious surfaces not only indicate urbanization but also are major contributors to the adverse impacts of urbanization on watersheds (Arnold & Gibbons, 1996; Cappiella & Brown, 2001; Schueler, 1994). Arnold & Gibbons (1996) identified four ways in which impervious surfaces degrade the health of receiving streams. They (1) contribute to hydrologic changes that degrade waterways; (2) are a major component of the intensive land uses that generate pollution; (3) prevent natural pollutant filtration in the soil by preventing percolation; and (4) serve as an efficient conveyance system for transporting pollutants into waterways.

Table 4 shows comparisons of the mean scores of the new urban and conventional developments in greenfields and infill sites for five categories of impervious surface reduction techniques. For each technique category, an index was calculated by summing the number of techniques employed by a given development (see Appendix Table A-1 for details of the technique category). Findings indicate that for both greenfields and infill sites, four of the five techniques were significantly more likely to be used in new urban developments than in conventional ones. Three of these differences indicate that the new urban developments were more effective in reducing impervious surfaces designed to accommodate automobiles, including modifications of streets/roadways (see Figure 4), driveways/alleyways, and parking areas; the fourth difference involves reducing the imperviousness of buildings. Figure 5, for example, illustrates the narrower streets and other features of new urban design that produce less impervious surface.

Only sidewalk/pathway techniques to reduce impervious cover were used more by conventional than new urban developments. The lower scores in new urban developments could be due to their stronger pedestrian orientation. New urbanism encourages pedestrian use, with features such as sidewalks on both sides of streets (see Figure 5). Sidewalk surfaces that allow for stormwater infiltration (e.g., porous pavement using lattice concrete or replacement of concrete with wood chips, gravel, or other pervious material) are not conducive to intensive pedestrian use and thus are more frequently discouraged in new urban developments.

While protecting sensitive areas and reducing impervious cover lessen stormwater runoff and lower pollutant loadings, urban stormwater BMPs treat the qual-

TABLE 4. Mean number of techniques used to reduce and modify impervious cover by technique category.

	Greenfield [n = 32]		Infill [n = 18]	
Technique category	New Urban	Conventional	New Urban	Conventional
Streets/roadways (maximum = 15)	7.44	2.53**	5.06	2.56**
Driveways/alleyways (maximum = 9)	2.50	.56**	.94	.50**
Parking areas (maximum = 7)	1.78	.12**	1.72	.06**
Building design/rooftops (maximum = 4)	.94	.53**	1.17	.28**
Sidewalks/pathways (maximum = 4)	.53	.67	.17	.28

Note: Comparisons of means show t-values that are significantly different for *$p < .1$ and **$p < .01$.

ity and quantity of runoff generated by imperviousness. Table 5 shows comparisons of the percentages of the new urban and conventional developments in greenfields and infill sites using seven types of stormwater BMPs that are designed to replicate predevelopment stream hydrology and water quality.

In the greenfields, the new urban developments strongly differed from the conventional developments in the application of BMPs. Six BMPs were used by a substantially higher percentage of the new urban developments, with the differences ranging from 19% more for landscaping sections of yards for detention and infiltration to 57% more for landscaping of open spaces in commercial areas (see Figure 6). Landscaping of streets to encourage stormwater infiltration was used by a small but slightly higher percentage of the new urban developments (9% versus 3%).

The developments in the infill sites did not show such a pronounced distinction in use of BMPs. The new urban developments used landscaping of streets to encourage infiltration by a slightly greater percentage (6% more), tree replacement by a moderately greater per-

FIGURE 4. Carpenter Village, NC. Flat curbs promote sheet flow off streets onto grassy swales or into bioretention area.

FIGURE 5. Chapel Hill, NC. Streetscapes of Parkside conventional development (left) and Southern Village new urban development. New urban development has narrower streets (26 versus 32 feet), smaller lots, and shallower setbacks that lead to reduced imperviousness; however, sidewalks are on both sides of street.

centage (17% more), and landscaping of commercial areas by a substantially greater percentage (50% more). Three BMPs (landscaping sections of residential yards for infiltration, locating detention ponds outside of floodplains, and tree preservation) were used by a moderately lower percentage (11–17% fewer) of the new urban developments, and one (bioretention ponds) was used by an equivalent percentage of both. Consistent with our interpretation of findings regarding sensitive area protection, the lower emphasis on using BMPs in infill sites compared to greenfields could be due to a lack of open spaces needed for installing BMPs in built-up infill areas. Moreover, as noted, new urban designers are creating development codes that guide building practice regarding environmental protection, but more attention is being given to greenfield development than to urban infill sites (see, e.g., Duany Plater-Zyberk & Company, 2001).

Conclusions and Recommendations

Does new urbanism offer a greener alternative to sprawl in greenfields? Our study findings show that new urban developments are neither a deep green ideal nor an intensively paved version of sprawl with short front lots, porches, and grid streets. Findings in greenfields reveal that new urban developments are more effective in incorporating watershed protection techniques than

TABLE 5. Percentages of developments that use BMPs to treat stormwater runoff.

	Greenfield (%) [n = 32]		Infill (%) [n = 18]	
BMP	New Urban	Conventional	New Urban	Conventional
Landscaping sections of residential yards for infiltration	25	6**	0	17[a]
Bioretention ponds	44	19***	22	22[a]
Detention ponds outside of floodplains to limit pollutant flushing	41	19**	28	39
Landscaping of streets for infiltration	9	3[a]	17	11[a]
Landscaping of open space in commercial areas for infiltration	69	12***	50	0***
Tree preservation	91	58***	61	78
Tree replacement	72	47**	78	61

Note: Comparisons show Chi square values that are significantly different for *$p < .1$, **$p < .05$, and ***$p < .01$.

a. Not applicable: Chi square tests not valid, as 50% or more of cells had frequencies less than 5.

FIGURE 6. Carpenter Village, NC. Bioretention area is landscaped with water-tolerant trees and shrubs. This BMP uses multiple processes to remove pollutants from stormwater runoff, including absorption, microbial action, plant uptake, sedimentation, and filtration.

conventional developments. Most notably, a higher percentage of new urban developments protect hydrologically sensitive areas (e.g., natural drainage depressions, stream buffers, and steep slopes) that have a significant impact on mitigating the adverse impacts of urbanization on receiving waters. This finding is impressive, despite our sample of new urban developments having average gross densities that were more than two and one half times higher than conventional developments in greenfields (new urban = 7.18 dwelling units per acre; conventional = 2.77 dwelling units per acre). New urban developments in greenfields were also more likely to restore degraded stream environments, incorporate BMPs to mitigate harmful impacts of runoff, and use a greater average number of techniques to reduce and modify impervious surfaces.

In only two instances were the new urban developments less successful in protecting greenfield watersheds than the conventional developments. Specifically, the new urban developments were somewhat less likely to prohibit impervious uses in sensitive open spaces, and they used a slightly lower number of techniques to reduce impervious cover created by sidewalks. A tradeoff for these higher levels of impervious cover is the greater likelihood that new urban developments contain an interconnected bike and walkway system along streets and greenways to reduce dependence on autos. The environmental benefits of more pavement in these instances could be decreased air pollution and energy consumption and less pressure to pave other watersheds.

These findings are subject to mixed interpretations. A skeptical view contends that new urbanism in greenfields is little more than what planner Tripp Pollard (2001) calls "new suburbanism." According to this view, such new urban developments are nearly identical to conventional suburban sprawl, since both development patterns contribute to the loss of green spaces and degrade watersheds. Paving green spaces in pristine watersheds is a much less desirable development pattern than connecting new urban developments to developed areas in previously degraded watersheds. This concern is noteworthy, since 64% (32 out of 50) of the new urban developments in the five states included in this study are located in greenfields.

In contrast, a view supported by our findings contends that even if new urban developments are located in greenfields, they do more to protect watersheds than conventional developments. As noted, new urban developments pave over less land, use more BMPs, and protect and restore more sensitive areas than conventional developments. Moreover, new urban developments substantially reduce the amount of land consumed for each dwelling unit as indicated by the higher densities in the new urban developments in our study.

Does new urbanism offer a greener form of development in infill areas? Our findings show mixed results. New urban developments are more likely to incorporate impervious surface reduction techniques and restore degraded stream environments than conventional developments. However, new urban and conventional developments have equivalent levels of sensitive area protection and use of BMPs. Further, new urban developments in infill sites use a slightly lower number of techniques to reduce impervious cover of sidewalks, and a much lower percentage prohibit paving of sensitive open spaces. The higher level of paved sidewalks and, especially, the lower level of prohibiting pavement in open spaces are likely due to an emphasis on pedestrian orientation in the densely built up urban core.

Suggestions for the Future

These findings suggest the need for more attention to infill and redevelopment sites. First, new urban developments built in urban core areas should more effectively account for watershed impacts. One example from our study, the new urban development of Port Royal in South Carolina includes an innovative strategy that links wetland and wildlife habitat restoration, pollution control, and flood mitigation with redevelopment and revitalization. Other noteworthy examples include adaptations of conventional sprawl development projects in urban core zones that demonstrate how to lessen the adverse impacts on watersheds through innovative practices. Projects such as The Crossings in Mountain View, California, and Winter Park Mall in Winter Park, Florida, entail razing or reconfiguring the trademark of sprawl—shopping malls and the vast parking lots that surround them—to mixed-use developments that incorporate a variety of BMPs such as bioretention facilities, permeable pavements, and swales.[11] These cases demonstrate how designers of new urban developments in infill sites can move beyond the current state of practice in watershed protection.

Second, emphasis should be given to building more new urban projects in infill sites. Recall that only 18 of the 50 new urban projects in this study were infill developments. Ducker and Owens (2000), for example, offer a range of regulatory, incentive, and investment strategies to foster infill development. Zoning regulations can be amended to allow mixed land uses on vacant urban lots in existing residential neighborhoods zoned as single-family zoning districts. Special neighborhood-conservation overlay zoning districts can enhance new urban infill projects and protect neighborhood character. These changes in zoning ordinances require amending the list of permitted uses for each district, as well as adjusting setbacks and density limits to enhance the feasibility of infill by new urban development. The focus of these changes is to address neighborhood compatibility issues often raised by the existing populace. Pioneering brownfield programs are available that encourage reuse of old industrial sites by limiting liability of new occupants for past environmental problems. Other tools for promoting infill development include creation of municipal service districts to finance inner-city revitalization, state and federal tax credits for renovation of historic structures, public investments in critical public facilities (schools, public buildings, and transit), and eliminating federal housing and highway subsidies that make it cheaper to build in greenfields.

Finally, more research should be focused on institutional and political factors that may influence the degree to which new urban developments account for environmental protection. Several potentially important factors that might affect the extent to which new urban developments account for watershed protection were not evaluated in this study. While greenfield new urban projects account for watershed protection more than conventional development, this support is not entirely due to new urban development codes and standards. As noted, these codes give only limited attention to the environment and especially to watershed protection. Most of the literature on new urbanism deals with physical design, which strongly relies on persuasive graphic renderings of new urbanism and the force of normative reasoning, but gives little attention to the process of political change. Institutional and political factors could thus be important in explaining support for new urbanism and the integration of environmental protection measures (Abbott, 2001).

Questions that could guide future investigations include:

- What is the influence of citizen demand for change in conventional development practices on local development policy?
- How important is local government commitment and capability to plan for more sustainable development?
- Are local governments under state planning mandates that advance compact development and environmental protection concepts more likely to plan for change than local governments in states without mandates?
- How can big state government bureaucracies, notably transportation departments, be induced to reinvent themselves to support change in conventional practices?

- What market mechanisms should be used to change conventional development patterns to protect the environment?

Despite its emphasis on high densities, new urbanism holds considerable promise for reducing environmental degradation caused by development. Low-impact design techniques for protecting sensitive open spaces, reducing impervious cover, and infiltrating polluted runoff may allow new urban developments to become a more environmentally compatible alternative to sprawl. The proliferation of new urban developments offer laboratories for testing new ideas on how best to integrate low-impact design alternatives into urban form. Planning practitioners and researchers should carefully evaluate these experiments as they evolve and educate the public, developers, and decision makers about how best to advance sustainable development.

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NOTES

1. The authors have observed a new urban development built on steep slopes (Southern Village, NC) and another project that was insensitive to some portions of upland woodlands (Middleton Hills, WI).
2. Schueler (1994) compared imperviousness of cluster developments with low-density sprawl developments, but did not include new urban developments in the study. Nevertheless, the study results are valid when considering new urban developments since these incorporate the basic compact design features of cluster developments.
3. Burby et al. (2001) have provided a thorough review of the literature on the adverse effects of compact development in creating risks posed by hazards that can be worse than in a comparable area of low-density development. For example, compared to low-density development, flooding could substantially increase (and water quality could be more severely degraded) if compact development were to take place in a small, pristine watershed on a greenfield site at the periphery of an already developed area. Alternatively, Burby and his colleagues contended that increased flooding from runoff and degradation may not occur if compact development were to take place in a more appropriate infill location within a metropolitan area where watersheds are already built up and degraded.
4. A review of urban designer Peter Calthorpe's (1993) widely used model standards (or "guiding principles") for new urban development also gives limited attention to spatial conservation concepts. Only 5 out of 72 principles deal with the environment, and of these only 1 addresses watershed protection by stating that the "drainage system should recharge on-site groundwater through biological retention and filtration areas" (p. 74). This single principle is obviously too vaguely defined to guide development in ways that minimize the impact of runoff. In contrast to the 1/2 page of text devoted to runoff and 5 pages on the environment in general, 43 pages cover 67 principles that focus on urban design concerns dealing with community character and sense of place.

   The recent SmartCode produced by Duany Plater-Zyberk & Company (2001) reflects this concern, as well. The code offers the most comprehensive, integrated, and holistic set of guidelines produced to date for creating new urban developments: Detailed development standards are adapted to six zones along a transect system extending from urban core to rural preserves. In keeping with the basic goals of new urbanism, the SmartCode aims to support community character, sense of place, and pedestrian movement. Tables of detailed design standards for building disposition, configuration, and function, as well as parking, vehicular lanes, civic space, and streetscapes, are provided for each zone. However, considerably less attention is given to environmental protection. A generic list of sensitive areas to be protected (e.g., open waters, wetlands, wildlife habitat, and riparian corridors) is provided for rural zones but no attention is given to environmental protection in urban zones.
5. Streams, riparian areas, and floodplains in urbanizing basins cannot be restored to a pristine state, but only to a functional state. The term "restoration" is used loosely in this study, which is also the case throughout the literature (Rosgen, 1996, 1997).
6. The matched pairs of projects (new urban and conventional) included in our North Carolina sample are located in coastal and inland areas. All pairs of projects in our sample for Maryland and Virginia are in the Chesapeake Bay drainage basin.
7. A total of 32 of 34 local governments responded to the telephone survey. One local government that did not respond contained three new urban projects. In the other local government, the staff planner could not identify a conventional development that matched the new urban development in its jurisdiction.
8. Because developments are labeled "new urban" does not necessarily mean that they are. We thus asked all planning staff respondents to indicate whether the new urban project located in their community contained a mix of residential, civic, and commercial land uses. Compared to the conventional developments, the new urban developments showed a considerably higher percentage of mixed uses in both greenfields (100% versus 25% mixed uses, $\chi^2 = 38.40$, $p < .01$) and infill sites (100% versus 11% mixed uses, $\chi^2 = 28.80$, $p < .01$). Further, we computed gross densities from answers to questions on the number of dwelling units and the number of acres. Compared to the conventional developments, average gross densities were much higher for the new urban developments in both greenfields (7.18 ver-

sus 2.77 dwelling units per acre, t-test = 1.85, $p < .1$) and infill sites (15.35 versus 6.47 dwelling units per acre, t-test = 3.36, $p < .01$). These results thus give us confidence that our data distinguish between new urban and conventional developments for these two design features.

9. In greenfield sites, the new urban developments had considerably greater difference in mean number of housing units (1137 versus 464 units, t-test = $p < .01$), had a small difference in mean project acreage (361 versus 195 acres, t-test = $p > .1$), and were considerably less completed (29% versus 65% completed, t-test = $p < .01$). In infill sites, the new urban developments had a small difference in mean number of housing units (697 versus 493 units, t-test = $p > .1$), had some difference in mean project acreage (568 versus 255 acres, t-test = $p > .1$), and were considerably less completed (37% versus 64% completed, t-test = $p <. 05$).
10. Results of the regression analysis for the sample of matched pairs of new urban and conventional developments for each type of location (greenfield or infill) revealed that standardized beta estimates for each of the three contextual characteristics were small (and not significant for $p < .1$) compared to the independent variable representing type of development (new urban or conventional). Regression results can be obtained from the lead author of this article.
11. Pollard (2001) identified these new urban projects and several others. For a more extensive review of adapting conventional residential, retail, and institutional development designs to ways that incorporate site design techniques that protect critical sensitive areas and BMPs, see EPA (2000).

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APPENDIX

TABLE A-1. Categories of techniques to reduce impervious surfaces.

Technique category	Techniques
Streets/roadways (15 items)	1. Narrower roads than in other recent projects. 2. Shorter roads than in other recent projects. 3. Hourglass residential roads. 4. Straight roads with less curvature. 5. Right angle intersections (four way and T-stop). 6. Fewer cul-de-sacs. 7. If cul-de-sacs, smaller radii. 8. If cul-de-sacs, "doughnut" style green (not asphalt) centers. 9. Hammerhead-shaped turnarounds. 10. Grass swales instead of curbs and gutters for storm drainage. 11. Narrower lots with smaller frontages. 12. Shorter side-yard setbacks on lots. 13. Streets oriented not to run parallel to gradient. 14. If any roundabouts or traffic signals, "doughnut" style green centers. 15. Porous pavement or latticed concrete for streets and roads.
Driveways/alleyways (9 items)	1. Shared driveways. 2. Strip driveways (two tire-wide concrete strips with grassy median). 3. Strip alleyways. 4. Narrower driveways than in other recent projects. 5. Shorter driveways. 6. If alleyways, narrower than in other recent projects. 7. If alleyways, shorter. 8. Alleyways oriented not to run parallel to gradient (steepest slope). 9. Porous pavement or latticed concrete for driveways/ alleyways.
Parking areas (7 items)	1. Replace two-way streets with one-way traffic on one side and angled parking on the other. 2. Narrower parking stalls than in other recent projects. 3. Lower parking ratios. 4. Shared parking facilities in mixed-use areas. 5. Vertical parking structures. 6. Replace parking lot drains with permeable spillover areas. 7. Porous pavement or latticed concrete for parking areas.
Building design/rooftops (4 items)	1. Two- and three-story buildings. 2. Smaller roof envelopes than in other recent projects. 3. Building features to channel runoff to pervious ground cover or rain barrels. 4. Rooftop gardens.
Sidewalks/pathways (4 items)	1. Sidewalk on only one side of streets. 2. Narrower sidewalks than in other recent projects. 3. Porous pavement or latticed concrete for sidewalks. 4. Replace concrete with gravel, woodchips, or other pervious material for pathways.